DESIGN TECHNIQUES OF "SERVING AREA VALUE ENGINEERING"

CONTENTS

1. GENERAL

1.1 This section provides REA Borrowers, consulting engineers and other interested parties with new recommendations using the Serving Area Value Engineering (SAVE) concept for the design of rural telephone plant.

1.2 This design method has two basic purposes:

a) To provide a systematic and consistent approach to the use of electronics on an economical basis. It provides for a circuit pricing technique to compare costs on each route for the different facilities. Whether interface equipment is used or not, the design procedure is recommended for cable sizing and the use of electronics.

b) To provide for interface equipment which separates the pairs to be used by installers and operating personnel. It is recommended that the distribution pairs available to the installer personnel generally have no load coils beyond the interface. The feeder circuits toward the office will have load coils, electronic equipment or whatever is needed to provide proper transmission from this point. These are either physical feeder pairs or via carrier pairs.

1.3 The basic building block of the new design method is a load coil bounded design area. See the diagram at the beginning of Section 3 (3.01) where "DA" means DESIGN AREA and "CUM" means CUMULATIVE. The five year estimates of the subscribers within these areas become the basis for the design. One or more such areas become a five year (or longer) serving area. Subscribers within the resulting serving area are connected to cable pairs which are interconnected to feeder pairs at a control point called the Serving Area Interface (SAI). Feeder circuits from the central office are connected at the interface to the distribution pairs to the subscribers.

1.4 This TE&CM has been written for D66 loading sections, but the design concepts can be used for H88 loaded plant. See Section 232 for the limitations for H88.

2. SERVING AREA DESIGN CONSIDERATIONS

2.1 Area Served by an Interface

2.11 Loading is not required up to 18 KF from the central office. Therefore, the first interface beyond the central office could be out four load sections. Interfaces are expected inside this distance to provide for control of distribution pairs and because density is generally high in or near towns. Also, routes converge in this area and major route junctions should be considered for SAI's. Of course, the mainframe is the first interface.

2.12 Physical circuits 18 KF and beyond from the central office will require loaded cable pairs. For D66 loaded exchanges, if the DA (Design Area) starts at a load point, the serving area can easily extend 2 load sections without loading of distribution pairs (within 9 KF). If longer serving areas were used, the loading system would need to extend into the distribution pairs. With non loaded distribution pairs the distance between SAI's will be two load or DA sections.

2.13 In applying grouped station carrier at a SAI, the length of the distribution pair must observe the ohms loop limit of the carrier equipment beyond the subscriber terminal (250 to 400 ohms). For 24 gauge plant this would be one load section. Certain grouped carrier will require coarser gauge pairs to cover the limit of two load coil sections. Use existing coarse gauge pairs when available and consider 22 gauge for small size cable additions.

2.14 In applying distributed station carrier, the subscriber terminal can be placed very close to the subscriber and the voice drop limit is not restricting.

2.15 From a digital subscriber carrier terminal, loading is not needed within the first 3 load sections using 24 gauge cable. The longest circuits should be limited to six D66 load points unless transmission is checked. Interfaces beyond the terminal are recommended for control purposes on the longer loaded voice frequency extensions off of the subscriber carrier such as at three load sections beyond the carrier. It is advantageous to group digital systems as much as possible since AC power must be provided at the subscriber carrier location. When three or more digital systems are required at a location, consider the use of a carrier concentrator system. If longer circuits are required from the subscriber terminal and gain devices have to be used at voice frequencies, the subscriber terminal must be placed midpoint between two load coils at a half section point. Refer to TE&CM Section 232.

2.16 Consider concentrators for groups of subscribers using physical circuits for trunks. Concentrators using physical circuits for trunks should follow the criteria for transmission for physical circuits from the central office. Concentrators using carrier trunks should use the transmission criteria for carrier.

2.17 Interfaces are recommended to be at load coil locations and/or major road junctions whenever practical. Load coils would not be located at an SAI which is not at the proper loading space interval. The end section limitations from the last load point must be observed as discussed in TE&CM Section 232.

2.18 Where two cable routes come into an interface, there should be a DA block for each. Each block is used for the cables on that route. The CUM (Cumulative) Block will include both routes.

2.2 Development of Cable Cost Information and Decision Tables

2.21 Referring to Exhibit 1 it has been found that reinforcing cables are generally a uniform size between load coils using this method of design; therefore, cost data has been presented and can be conveniently summarized in that form.

2.22 Since in many instances an adequate number of distribution housings are in place, new ones are priced separately rather than averaged.

2.23 A BD4 housing is included in the cost of a channel of distributed type carrier, so the carrier can be mounted inside the housing at a new location or a changeout.

2.24 Most load coils being added, will be in 25 pair (to a lesser extent 5 pair) splice multiples.

2.25 See TE&CM Section 629, "Cable Plant Layout" and TE&CM Section 648, "Serving Area Value Engineering - (Physical Plant)" for a more detailed outside plant discussion.

2.3 Electronic Decision Table

2.31 The 24 gauge decision table shown in Exhibit 2 is based on the fact that at distances where carrier may prove economical, electronic equipment (loop extenders and voice frequency repeaters) will be required on the alternative voice frequency feeder circuits.

2.32 In Exhibit 2, it is assumed that even though it may not be true initially the loop extenders (or long line adapters) and voice frequency repeaters will be in an 80 percent efficient common mode group for most of their life. Load coils normally have the same annual costs as cable. On feeder circuits where loaded pairs compete with carrier, it is now expected that the cable pairs on which they are initially installed will gradually be converted to carrier circuits or to non-loaded distribution pairs. Load coils are therefore given the same annual cost percentage as electronic equipment in the decision chart.

2.33 Exhibit 2 indicates that the cost of one circuit of voice frequency "electronic" equipment required for physical feeders is subtracted from the cost of various types of carrier channels.

2.34 The difference in costs developed in Paragraph 2.33 can be compared to the cost of a physical feeder pair if the difference in annual

charges between cable and electronics is recognized. That is why the electronic annual charge (23 percent assumed) is divided by the cable annual charge (19 percent assumed) and the result (1.25) multiplied by the carrier differential cost developed in Paragraph 2.33. The results are shown in columns (h), (i) and (j) of Exhibit 2.

2.35 For example, at load coil location Number 12, if a physical feeder cable pair costs more than $469, Exhibit 2 indicates PCM or grouped station carrier should be used.

2.4 Cost Comparisons

2.41 Costs for cables and carrier channel feeders used in this section are included in the Exhibits. It is recommended that Section 232 be consulted for guidelines on how to develop carrier costs using updated information for the design under consideration. Up-to-date cable and carrier cost tables should be developed to use in lieu of those in the Exhibits. The tables do include three ranges of prices for cables but the middle range was used in the examples.

2.42 The cost per load section (DA) pair for the size cable used is added from one DA to the next beginning at the CO to get the cost per pair at each point. For part of a DA, multiply the fraction of the section by the cost for the section. This is usually necessary for branches.

2.43 The cost for carrier provides that systems may be filled to capacity. Use Appendix 1, Table 1 to provide for extra carrier pairs for future expansion to accommodate the number of circuits using the required fill factors. The carrier cost per channel at a load section shown on the Exhibit 2 table should also account for the physical circuits used for the carrier system. Multiply the physical pair cost at the proposed carrier location by the number of initial carrier pairs needed, divide by the number of design channels in the system and add this figure to the carrier channel cost.

2.44 The costs are shown above the load coil point and the breakeven point is noted with an asterisk (*). Carrier should be used to serve subscribers beyond this point. Please refer to Phase I drawing at the B11A pedestal location.

2.45 The initial physical design should disregard existing station or subscriber carrier. This will indicate whether the existing carrier might better be relocated.

2.5 Cable Pair Requirements

2.51 The cable pair requirements are based on actual pairs needed. The pair requirements will include subscriber pairs, carrier pairs for subscribers and trunk pairs, either physical or carrier. Using the total pair requirements consult Appendix 1, Table 1, for the proper fill factor for the type growth area involved. This factor times the pair requirement less the existing cable pairs equals the new cable pairs needed including spares. The appropriate cable providing at least this many pairs should be provided. The fill factor table takes into account present worth of annual charges and delays larger cables.

2.52 The method and criteria of assigning pair groups is given in TE&CM Section 230 and 629.

2.6 Other Design Considerations

2.61 Of major importance is the available space for placing buried cables in the ground or aerial cables on existing pole lines. Revised tables should be prepared to cover additional costs where they are anticipated due to such problems.

2.62 Delay a cable addition if it is for providing spare pairs.

2.63 The minimum buried plant addition should be six pair cable and the minimum aerial addition should be DW3 except in sparsely populated areas. In such cases, smaller sizes can be used for at least two load sections. In more dense areas, consider a 12 pair cable as minimum.

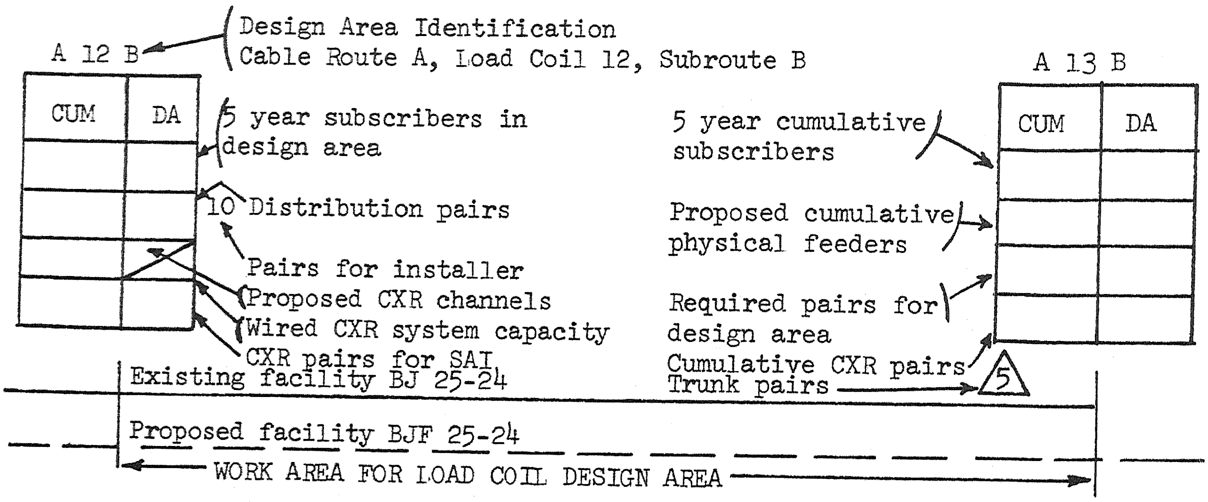
2.64 Distributed station carrier should be used sparingly, mostly to delay an addition of some length to an existing small cable or for very sparsely populated areas.

2.65 In sparsely populated areas, consideration should be given to providing distribution pairs both ways from an SAI, thus doubling the size of the serving area. This is especially true in the carrier service area. Cable pairs are often available in such instances. This reduces the number of carrier systems, improves their fill and reduces interfaces. Care should be exercised closer to the office especially with physical feeders since this requires pairs both ways in the portion toward the central office whereas the penalty with carrier is minimal. Increasing cable sizes in this section may cost as much as an interface and degrade transmission.

2.66 For small SAI's where an existing pedestal is adequate, plan to retain the pedestal and devise a simple method to mark the distribution and feeder pairs that the installer is to use.

3. DESIGN PROCEDURE

3.01 Block Identification Information



3.1 In Phase I: Locate the load coils and any major subroute where an SAI is proposed. Show the CUM-DA blocks for each, as above; show the five year subscribers for the load coil area (Design Area) in the DA block, and the existing retainable facilities as a solid line under the blocks. Next accumulate the five year subscribers and show them in CUM block; show the trunk pairs (if any) in a triangle under the CUM block and determine the required pairs needed. Determine what growth rate will be used on each route or area. (A medium growth rate was used for all the examples.) Determine the total cable pairs needed using the factor from Appendix 1, Table 1 and the cable addition needed for an all physical plant. Determine the cost per pair to each load point, the carrier cost for each load point and put these figures over the block identification number. The carrier cost need not be computed until the physical cost exceeds the carrier cost. Mark the break-even point for the carrier with an asterisk (*).
Note: If no carrier is proposed, go to Phase III after Phase I and disregard carrier information and the recalculation of new cable sizes. Only locate the SAI's and show the distribution and feeder pairs.

(SEE PHASE I DRAWING)

3.2 In Phase II: Determine appropriate carrier types and locations to use beyond the breakeven points, remembering their limitations. Try to fill the systems as much as possible. When they have been located, mark them as Serving Area Interface (SAI) points over the identification block. Beginning at the far end, show the distribution pairs to each SAI in the distribution pair DA block, the carrier channels required over the design system capacity for the SAI in the DA block. Show the carrier pairs needed in the bottom DA block for the systems at this SAI. Using the regular fill factors, determine whether extra carrier pairs are needed beyond the five year period for future

growth. On the CUM side of the SAI block show the total carrier pairs needed in the cumulative carrier pair block. Show pairs if any for serving subscribers on a physical basis. Show the total circuits needed in the CUM block. Reduce the cable additions needed due to the carrier service.

Since the carrier channels wired but not equipped are available generally only at the SAI involved, they are shown only there. To check subscribers served by carrier at any point, deduct the physical feeders from the CUM subscribers. It is suggested that equipped and wired channels be shown at the CO for each route.

(SEE PHASE II DRAWING)

3.21 The backfeed method: This may be used for sparse areas to fill grouped carrier systems better and reduce the number of SAI's. It may also be employed for digital carrier systems to reduce the number of installations, however, care must be exercised that the backfeed portion is not too long and thus become uneconomical.

Locate the SAI's such that subscribers are served both ways from the carrier location. Use an arrow from the DA block to the CUM block in the design areas toward the CO to indicate a backfeed. Show the subscribers or distribution pairs needed forward from the SAI in the DA block forward from the SAI. The carrier channels needed will be this figure plus those in the distribution block at the SAI. The cable requirements forward from the SAI will be based on the carrier pairs plus the distribution pairs needed on the backfeed in the DA block in the normal manner.

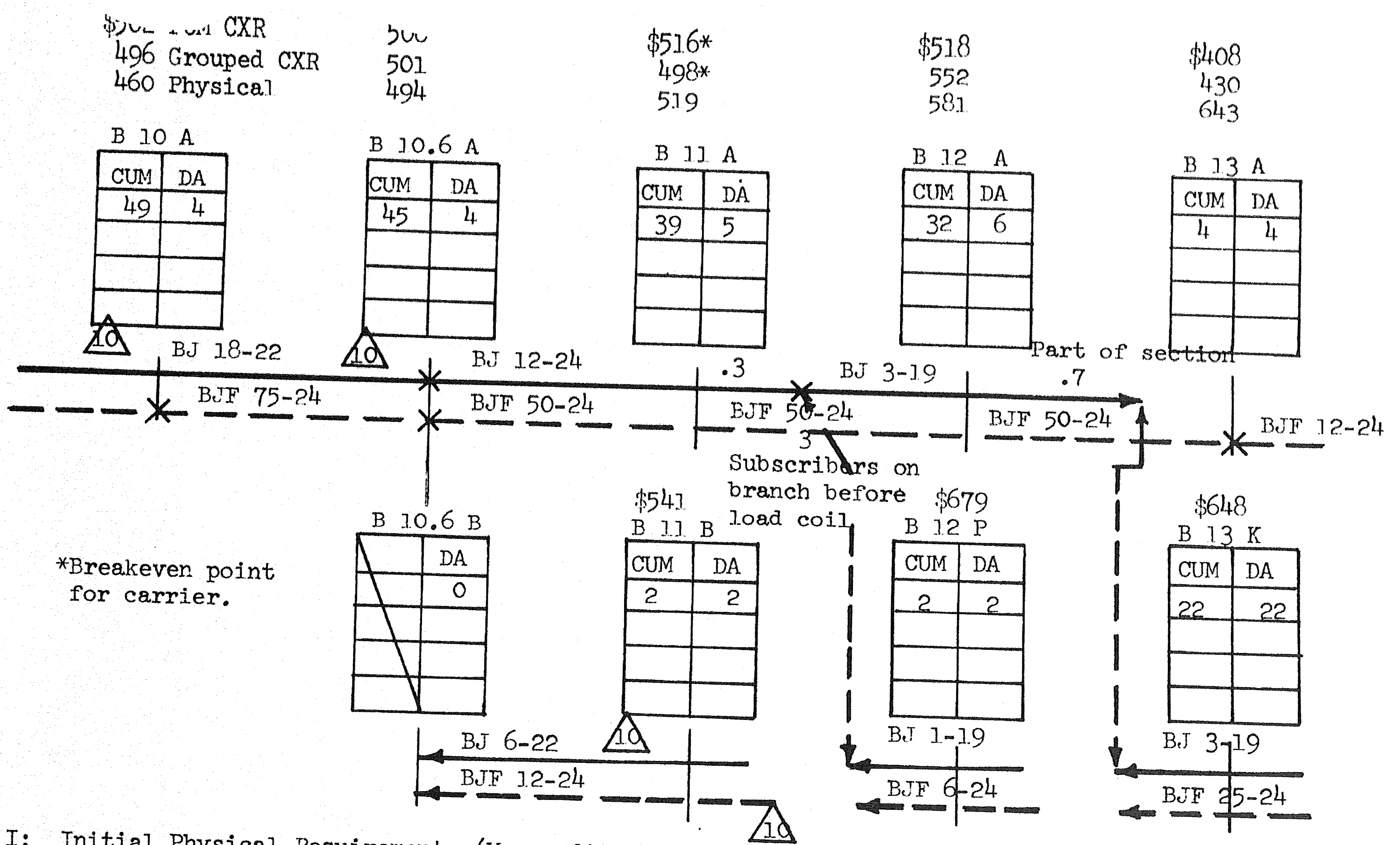
(SEE PHASE II DRAWING CARRIER BACKFEED METHOD)

3.3 In Phase III: Complete the design inside the breakeven point beginning at the SAI where the nearest carrier installation is proposed. Accumulate the carrier pairs with all branches into the office. Locate the fourth load point from the CO and show SAI's here and at every other load point out to the breakeven point. Inside the fourth load point non-loaded pairs are used, so locate any SAI's for the benefit of the installer paying special attention to densities and to junctions of routes. Show the distribution pairs needed in the DA block at each SAI. Show the total circuit requirements in the CUM block. Recalculate the new cable sizes needed between load points if carrier is used.

(SEE PHASE III DRAWING)

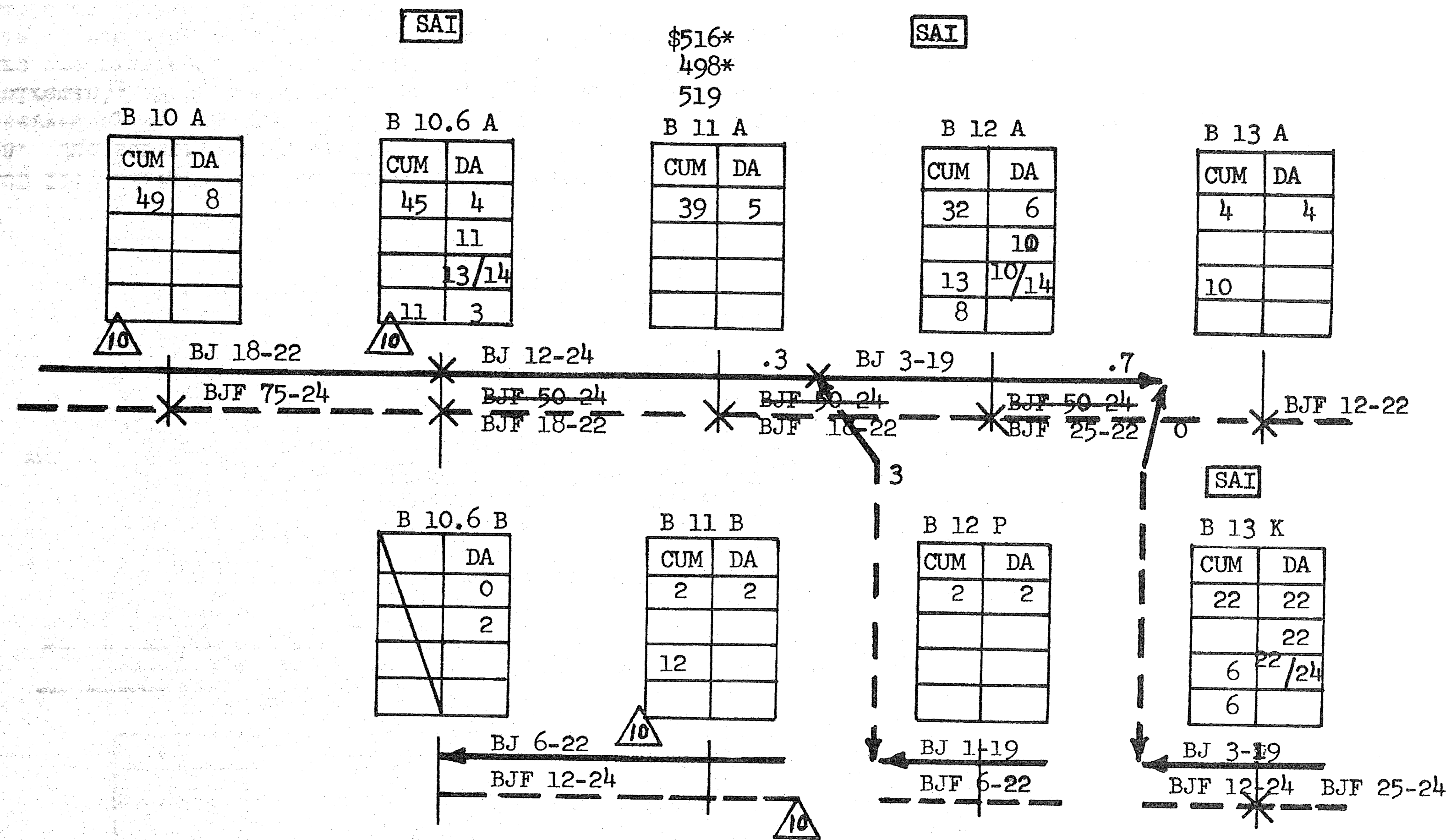
3.4 In Phase IV: Review the cable additions. Consider delaying additions providing only spare pairs. Consider changes in cable sizes to better use the cable plant where such changes are not too costly. Show the pairs to be available to the installer at each SAI. Show the housing type above the SAI block.

(SEE PHASE IV DRAWING)



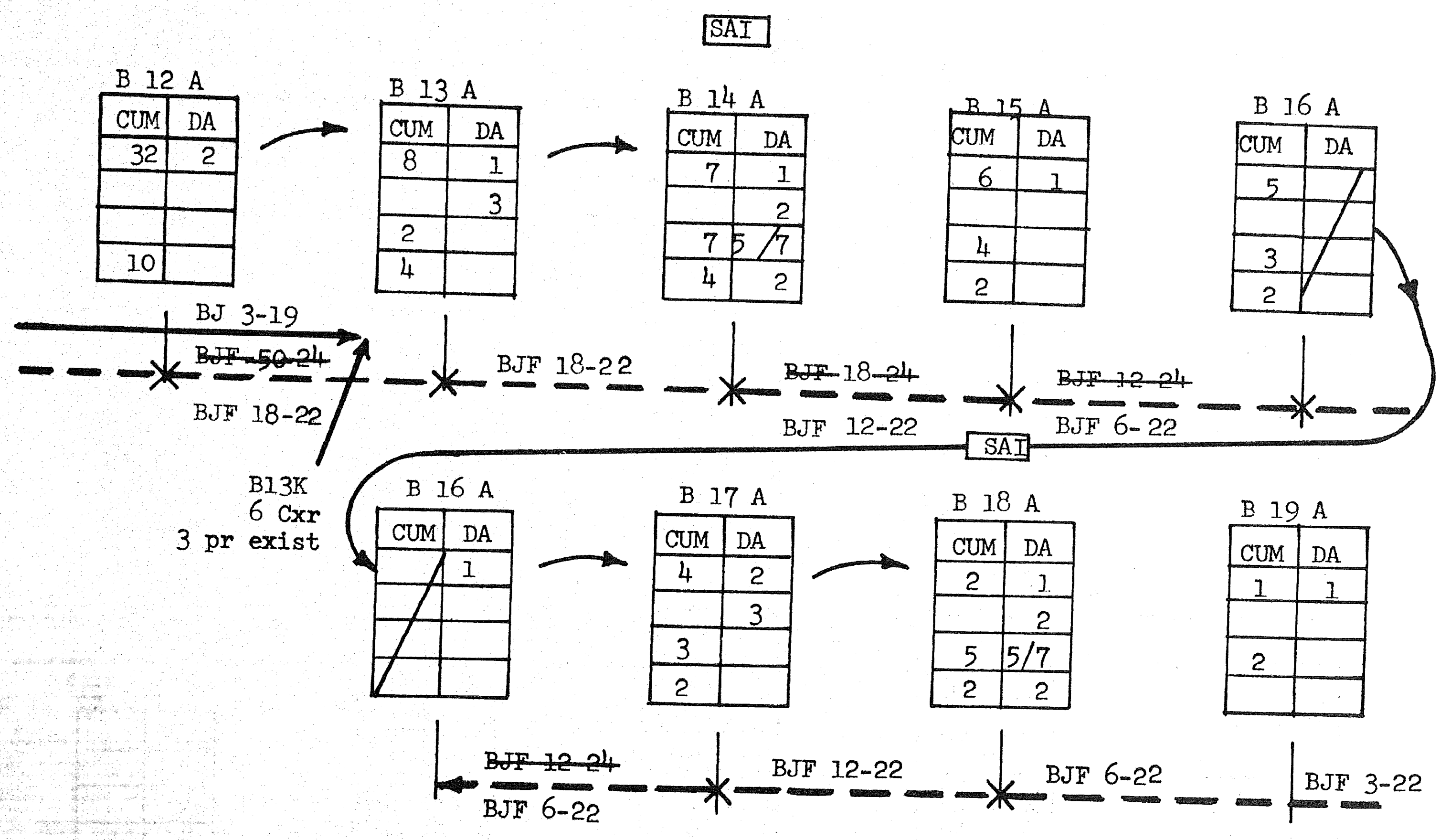
PHASE I: Initial Physical Requirements (Use medium growth factors on Table 1, Appendix 1.) Work Area is between vertical lines of load coil blocks. Put 5 year subscribers in DA blocks and accumulate in CUM blocks. Though it is really not large, we are showing for guide purposes B subroute as a major intersection with block information at this point (0.6 load section from B 10A). Cable addition between B 10 A and B 10.6A=45 from CUM and 10 Trunk from B 10.6 A and 4 from DA at B 10 A=59 x factor of 1.18=70 needed with spares less 18 pairs existing=52. Add a 75 pair cable. B 10.6 B to B 11 B=(2+10) x 1.33-6=10 Add a 12 pair. Cable addition between B 10.6A+B 11 A=39 from CUM B 11 A+4 from DA at B 10.6 A=43 needed x 1.18 less 12 pairs existing=39 pairs. Add a 50 pair cable. Cost of physical circuit at B 10.6 A=460 at B 10 A + .6x56 for 75 pair (Exhibit 1)=$494. At B 11 A=494 + .4x62-$519. At B 11 B=494 + .4x117=$541. Cost of Grouped CXR at B 11 A=424 (Exhibit 2) + $\frac{519}{7}$ = 498. PCM=451+3x $\frac{519}{24}$=516. *Breakeven point for carrier.

PHASE I DRAWING



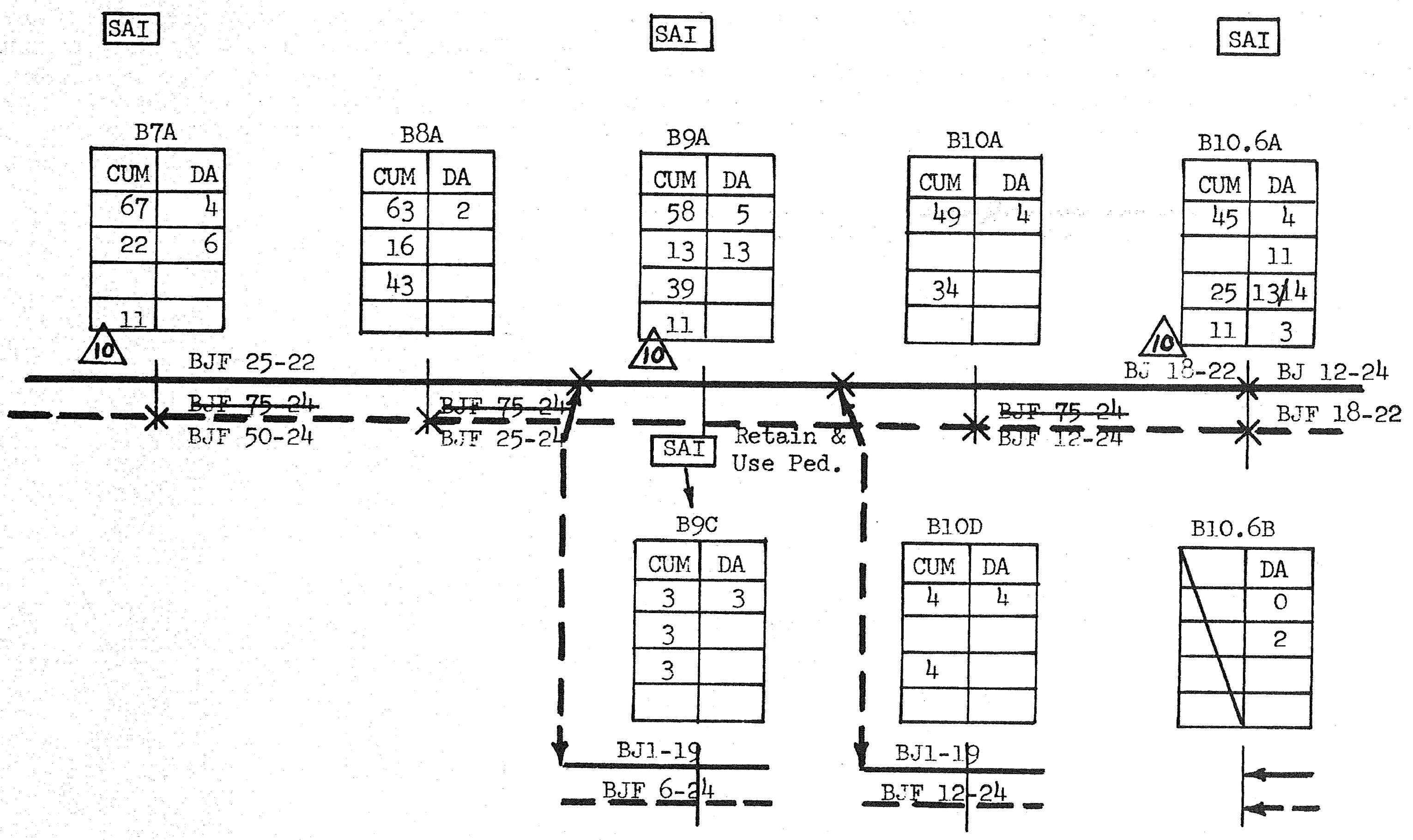
PHASE II DRAWING

PHASE II: Design beyond breakeven point. Consider carrier at load point 11 and beyond. Since B 10.6 is a major junction we will put an SAI here with station carrier though it is slightly inside the breakeven point. B 12 P will be a problem. We will use distributed carrier if the drop is too long on a closer inspection. We are showing 2 station carrier systems at B 12 A and a PCM system at B 13 K. Show equipped carrier channels over wired channel capacity in the DA block at the SAI as well as the carrier pairs in the DA and CUM blocks. Use fill factor table to tell if extra carrier systems will be needed in future and include extra carrier pairs needed. Show the distribution pairs in the DA block and the required pairs in the CUM block. Recalculate cable. B 12 A to B 13 A=4 from CUM at B 13 A, 6 CXR from B 13 K and 6 from DA at B 12 A x 1.33 = 22 pairs less 3 pair available = 19 pair. Add 25 pair. Cross out the 50 pair and show 25 pair.

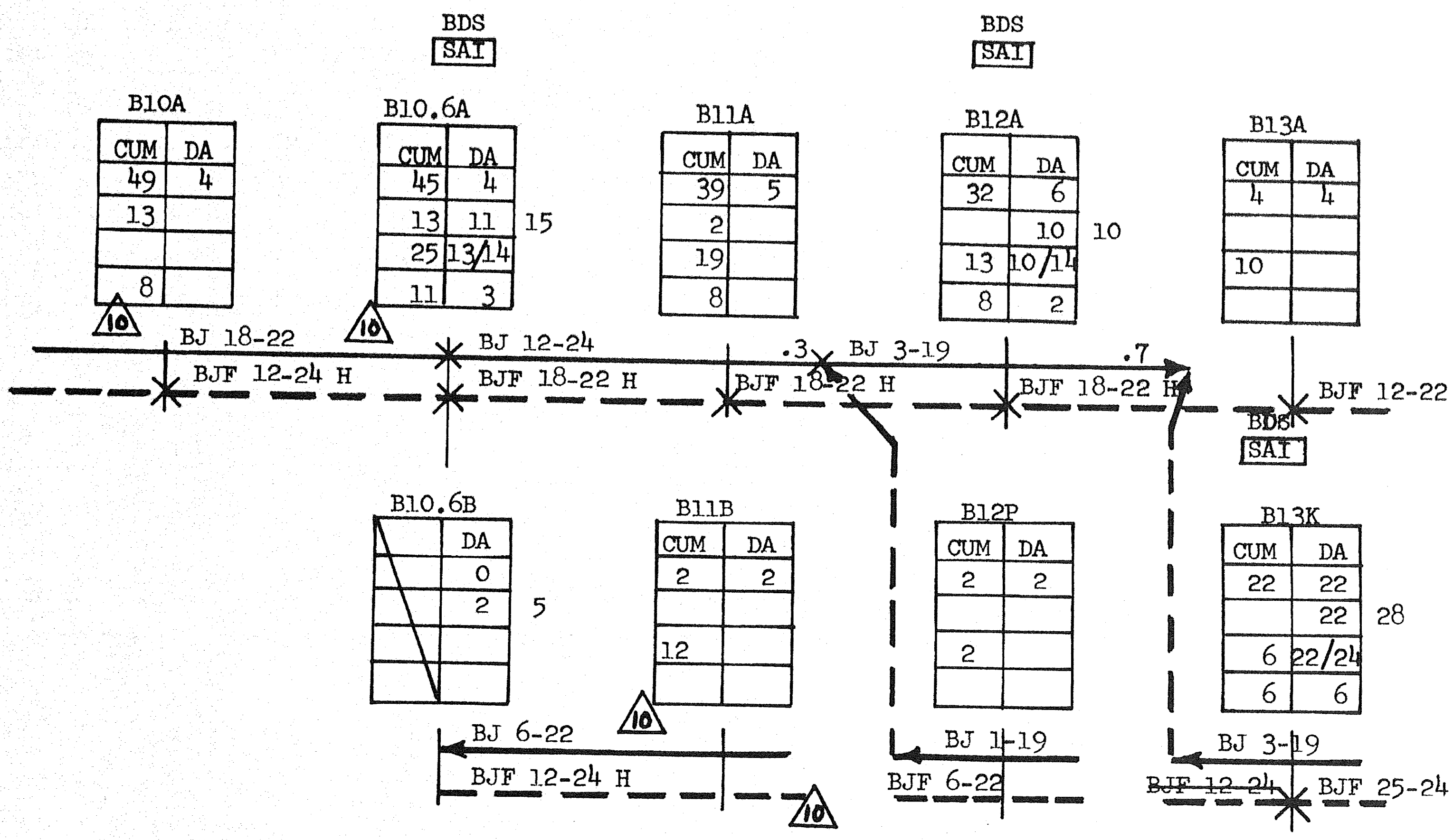


PHASE II DRAWING
CARRIER BACKFEED METHOD

PHASE II: Carrier backfeed method. For this sparse area, use station carrier. Locate one at B18A and one at B14A. One subscriber at B16A and two from B17A will equal three for the DA distribution pair block on B17A to be served by the carrier at B18A. With the two from the B18A distribution pair block makes a five channel requirement. With a medium growth area, a second carrier system will be needed beyond the 5-years so 2 carrier pairs are provided. Cable for B17A to B18A = (3 distribution + 2 carrier) x 2.0 =10 pair. Provide a 12 pair cable. From B16A to B17A = (1 + 2) x 2.0 = 6 pair. The required pairs are shown in the CUM block on this example as provided in Phase IV.



PHASE III: Design inside breakeven point. Locate SAI's. Show carrier pairs in CUM blocks inside the breakeven point. Show distribution pairs and feeder pairs at each SAI. Because end section at B9C will be too long from B7A use existing housing at B9C for SAI and mark pairs. Compute and show required pairs. Required pairs for B7A=16 feeder + 6 distribution + 11 carrier + 10 trunk=43 in B8A CUM block. Recompute cable. 43 x 1.18= 51 less 25 existing=26. Add 50 pair cable instead of 75 pair.



PHASE IV: Engineering judgment changes, pairs for installer and type housing at SAI's

If BJ3-19 is good into B13K delay 12 pair addition for future carrier circuits. Consider new cables at least smaller than 50 pair to be screened for PCM operation out to B13K. Consider also the 12 pair cable addition through B11B to be screened for future PCM trunks. At SAI's: All pairs available to the installer are put outside the distribution pairs block. At B12A show 10 for installer. At B10.6B show 5. At B13K show 28.

BURIED CABLE COST
FILLED-GOPHER SHIELD

UNIT		INSTALLED* COST PER D-66 SECTION			COST PER PAIR PER SECTION		
		LOW 85% of AVG.	AVERAGE	HIGH 115% of AVG.	LOW	AVERAGE	HIGH
BWF	2-22	690	$ 812	934	345	$406	467
BJF	6-24	959	1,128	1,297	160	188	216
BJF	6-22	1,028	1,209	1,390	171	202	232
BJF	12-24	1,197	1,408	1,619	100	117	135
BJF	12-22	1,397	1,643	1,889	116	137	157
BJF	18-24	1,391	1,637	1,883	77	91	105
BJF	18-22	1,673	1,968	2,263	93	109	126
BJF	25-24	1,710	2,012	2,314	68	80	93
BJF	25-22	1,996	2,348	2,700	80	94	108
BJF	50-24	2,639	3,105	3,571	53	62	71
BJF	75-24	3,558	4,186	4,814	47	56	64
BJF	100-24	4,208	4,950	5,693	42	50	57
BJF	150-24	5,908	6,950	7,993	39	46	53
BJF	200-24	7,820	9,200	10,580	39	46	53
BJF	300-24	11,475	13,500	15,525	38	45	52
BJF	400-24	15,300	18,000	20,700	38	45	52
BJF	600-24	22,950	27,000	31,050	38	45	52

	INSTALLED COST PER UNIT
BDF-3	$ 47
BDF-4	54
BDF-7	114
BDF-S (Small Serving Area Interface)	310
BDF-L (Large Serving Area Interface)	552
X CONNECT BLOCK	10
Load Coil	5
Concrete Pad for SAI	325
Electronic Housing -5'	600
Electronic Housing -7'	750

*Assumes 4.5 KF per section, including splicing and appropriate BM units. These costs are presented for suggested format only. Develop costs considering local conditions.

EXHIBIT 1 - OUTSIDE PLANT COST DATA

D-66 LOAD COIL LOCATIONS	CARRIER FEEDER COST: GROUPED STATION*	CARRIER FEEDER COST: PCM**	CARRIER FEEDER COST: DISTRIBUTED STATION***	VOICE FREQUENCY LINE TREATMENT COST: LOAD COILS	VOICE FREQUENCY LINE TREATMENT COST: COMMON MODE	VOICE FREQUENCY LINE TREATMENT COST: SUB TOTAL	ANNUAL COST CARRIER ADJUSTMENT****: GROUPED STATION CARRIER ADJUSTED COST	ANNUAL COST CARRIER ADJUSTMENT****: PCM CARRIER ADJUSTED COST	ANNUAL COST CARRIER ADJUSTMENT****: DISTRIBUTED STATION CARRIER ADJUSTED COST
(a)	(b)	(c)	(d)	(e)	(f)	(g=e+f)	h=1.25(b-g)	i=1.25 (c-g)	j=1.25(d-g)
1	$372	$388	$500	$ 0	$ 0	$ 0	$ 465	$ 485	625
2	372	399	500	0	0	0	465	498	625
3	372	410	500	15	0	15	446	494	606
4	372	410	500	20	0	20	440	487	600
5	413	421	550	25	0	25	485	495	656
6	413	432	550	30	0	30	479	502	650
7	413	443	550	35	0	35	472	510	644
8	454	443	600	40	0	40	517	504	700
9	454	454	600	45	60	105	436	436	619
10	454	465	600	50	60	110	430	444	613
11	454	476	600	55	60	115	424	451	606
12	495	476	650	60	60	120	469	445	663
13	495	487	650	65	60	# 225	338	328	425

*Includes $372 per grouped station carrier channel, plus $41 per channel prorated repeater cost.
**Includes $388 per PCM carrier channel, plus $11 per channel prorated repeater cost.
***Includes $500 per station carrier channel plus, $50 per channel prorated repeater cost.
****Annual Charges for Maintenance, Depreciation, Property Tax, Insurance, Cost of Money, Margin and Income Tax can be expressed as a percentage of investment for cables and electronics. The table assumes cable pairs can be 1.25 times the cost of a carrier channel for equal annual charges.
#Field mounted VF repeater would be required. Refer to TE&CM 232 Paragraph 2.13.

EXHIBIT 2 - 24 GAUGE DECISION TABLE

APPENDIX I

Use of Present Worth of Annual Charges In Broad Gauge Cable Size Decision Making

In building cable plant, it may be more economical to install one large cable now or a small one now and another small one later. A decision between these two alternatives should be based on a present worth of annual charges (PWAC) analysis.

Table 2 shows the number of years required between the installation of two equally sized small cables before they will prove more economical than installation of one large cable initially.

This table is based on a number of assumptions. Each borrower should consider his own requirements and vary these assumptions as needed. The assumptions are:

1) Cable costs are as in Exhibit 1 of TE&CM 231

2) Cost of money is 8%

3) Cable life is 25 years

4) The cost of the future cable is 1.2 times what it is today.

5) Cable annual charges are 19% of the initial cost (when depreciated over 25 year period).

6) Both cables are retired at the end of 25 years.

Since the annual charge rate is 19%, the annual charge for the larger cable will be

.19 x installed cost of larger cable.

The present worth of these annual charges is

$$(P/A)_{25}^{8} \times (.19 \times \text{installed cost of larger cable.})$$

where

$(P/A)_{25}^{8}$ = Present worth of an annuity (or present worth of a uniform series of payments) for 25 years at 8% cost of money.

This cable must now be compared with the present worth of annual charges for the two smaller sized cables.

The PWAC for the first small cable is

$$(P/A)_{25}^{8} \times (.19 \times \text{installed cost of smaller cable})$$

For the second cable, no annual charges are incurred until it is installed. If it is installed N years later the PWAC savings is

$$(P/A)_N^8 \times (.19 \times 1.2 \text{ installed cost of smaller cable.})$$

where

$(P/A)_N^8$ is the present worth of annual charges at 8% for N years and 1.2 is an inflation factor. (Second cable is installed N years later.)

Thus the total PWAC of the second small cable is:

$$(P/A)_{25}^8 \times (.19 \times 1.2 \times \text{installed cost of small cable.})$$
$$- \; (P/A)_N^8 \times (.19 \times 1.2 \times \text{installed cost of small cable.})$$

or

$$(.19 \times 1.2 \times \text{installed cost of small cable}) \times$$
$$(P/A)_{25}^8 - (P/A)_N^8$$

If N is small, (the second small cable can't be deferred for very long) it will be more economical to install a larger cable immediately. As N increases, the PWAC of the two cable plan decreases.

For a certain number of years N, the PWAC of the 2 plans will be equal. This number of years is termed the breakeven years. At any point beyond this, the two cable plan will be more economical. By equating the PWAC for the two plans, we can find how many years the second small cable must be deferred before it will prove economical.

PWAC of large cable = PWAC of first small cable
+ PWAC of second small cable.

$$(P/A)_{25}^8 \times (.19 \times \text{installed cost of large cable}) =$$
$$(P/A)_{25}^8 \times (.19 \times \text{installed cost of small cable}) +$$
$$(P/A)_{25}^8 - (P/A)_N^8 \times (.19 \times 1.2 \times \text{installed cost of small cable.})$$

By solving this equation for $(P/A)_N^8$ we can find the number of years the second cable must be deferred by looking up the value of $(P/A)_N^8$ in interest tables found in most engineering economy texts.

$$(P/A)_N^8 = \frac{2.2 \times \text{installed cost of small cable} - \text{installed cost of large cable}}{1.2 \times \text{installed cost of small cable.}} \times (P/A)_{25}^8$$

This formulation is used in the SAVE guidelines in determining percentage fill required for various growth rates and for various cable sizes. Essentially, a cable is installed at such a % fill that it will not need to be reinforced until it is economical to do so with another equally sized cable (based on a PWAC analysis).

The SAVE guidelines assume the following growth percentages (compounded annually):

Low Growth	=	2%
Medium Growth	=	6%
High Growth	=	8%

In some cases the PWAC technique will show cable fills of greater than 90% at the end of five years. In order to allow for bad pairs, inaccuracies in forecasts, etc., no cable is filled to more than 90% after five years under these guidelines.

Example:

Table 2 shows the breakeven years for two 12-pair cables vs one 25-pair cable is 10 years. This means that a 12-pair cable should be installed at such a % fill that it won't need reinforcement for 10 years.

In a medium growth area (6% growth), the number of subscribers at the end of 10 years will be 10 year subs. = existing subscribers x $(1.06)^{10}$

or

$$\text{10 year subs.} = \text{5 year subscribers x } (1.06)^{5}$$

If it is assumed that the cable will be filled at the end of the 10 years, the 5 year percent fill is $(1.06)^{-5}$ or 75%. In general, the formula is:

$$\text{\% Fill after 5 years} = (1+P)^{5-N}$$

where

P = Percent growth of area (expressed as a decimal)

N = Breakeven year from Figure 1

The number of pairs required for a 75% filled cable at the end of 5 years can be obtained by multiplying the 5 year subscribers by $\frac{1}{75\%} = \frac{1}{.75} = 1.33$

This is the number recorded in Table 1.

Because it is desired to record one factor for a range of cable sizes in the table, it will be necessary to round off between the different values for different cable sizes within a range.

For convenience in applying the factors to the SAVE design, the factors shown in Table 1 are plotted against the number of 5 year circuits rather than cable size. For example, in low growth areas, calculations like those above show that cables between three and 12 pair are to be 80% filled and 18 and 25 pair cables are to be 90% filled. Thus, the largest number of subscribers that can be served in a 12 pair cable is 9. If there are between one and nine subscribers in an area, they would be multiplied by 1/.8 or 1.25 to determine the pairs required. Since 10 subscribers cannot be served in a 12 pair cable at 80% fill, they would require a larger cable. Since cables of 18 and 25 pair are to be 90% filled in low growth areas, 5 year subscribers between 10 and 22 would be multiplied by 1/.9 or 1.11. (90% of 25 = 22) Since 23 subscribers cannot be served in a 25 pair cable at these fills, they also would require a larger cable, etc. The thresholds thus determined for low growth rate areas are applied to all growth rate areas.

TABLE 1

Fill Factor - to be multiplied by
5 year required circuits.*

Circuits Required	**GROWTH RATE LOW	MED	HIGH
1-9	1.25	2.0	2.5
10-22	1.11	1.33	1.4
23-67	1.11	1.18	1.25
68-135	1.11	1.11	1.18
136	1.11	1.11	1.11

*Number of 5 year subscribers x appropriate growth rate fill factor = minimum number of pairs required

**A growth rate should be used along each route which reflects the growth along that route, irrespective of growths on other routes.

Plan I Install 4.8 KF small cable initially and reinforce with an equal size cable after an economical deferral period. Assume future cost is 20% more than initial cost.

Plan II Install large cable initially which will have a 25 year life but not necessarily provide all the circuits required for 25 years.

Using present worth of annual charges technique find the minimum deferral period for the small reinforcing cable.

Large Cable versus Two Small Cables	Installed First Cost (Large Cable)	Installed First Cost (Small Cable)	Breakeven Year (N)
2-22 vs (1-19)+(1-19)	$ 812	$ 727	19+
6-24 vs (2-22)+(2-22)	1,085	812	12+
12-24 vs (6-24)+(6-24)	1,408	1,085	13+
25-24 vs (12-24)+(12-24)	2,012	1,408	10+
50-24 vs (25-24)+(25-24)	3,105	2,012	8+
100-24 vs (50-24)+(50-24)	4,950	3,105	7+
150-24 vs (75-24)+(75-24)	6,950	4,186	6+
200-24 vs (100-24)+(100-24)	9,200	4,950	3+
300-24 vs (150-24)+(150-24)	13,500	6,950	2+
400-24 vs (200-24)+(200-24)	18,000	9,200	2+
600-24 vs (300-24)+(300-24)	27,000	13,500	2+

Table 2 Breakeven years for Various Cable Sizes.

APPENDIX 2

The Decision Chart

At the end of Phase I, the Decision Chart is used to determine the break-even point. This determination is made by comparing the cost of a physical circuit with the cost of a carrier circuit. The decision chart is a tabulation of the costs of the various carrier systems as a function of distance from the C.O.

While carrier costs do not vary as much with distance from the C.O. as do physical costs, longer systems do require more repeaters and perhaps intermediate power feeds. These factors must be taken into account in setting up the decision chart. For details of the derivation of the equipment and installation costs of carrier, see TE&CM Section 232, Appendix A.

The comparison of the cost of carrier with the cost of Physical plant is to be done on a Present Worth of Annual Charges basis. In doing this it must be recognized that carrier annual charges are somewhat higher than physical plant annual charges. This is due to the fact that carrier has a shorter life and hence must be depreciated more rapidly as well as the fact that carrier is more expensive to maintain than physical plant.

In the decision chart, the carrier cost is multiplied by a factor which accounts for these differences. While the table given in the SAVE guidelines uses a factor of 1.25, it should be noted that this factor will vary between different borrowers. The derivation of the 1.25 factor presented below is included so that the consultant will be able to derive different factors to fit the existing situation. Use annual cost factors, depreciation, maintenance, etc., based on actual experience.

ANNUAL COSTS

	Carrier	Physical
Depreciation (Sinking Fund)	2.2%	1.4%
Maintenance	5.0%	1.5%
Property Tax	2.0%	2.0%
Cost of Money	8%	8%
Net Income (Margin)	2.3%	2.3%
Fed. Income Tax	2.3%	2.3%
	21.8%	17.5%

Carrier Adjustment Factor

$$\frac{21.8}{17.5} = 1.25$$

Certain items required in a physical design are, by their nature, subject to the same annual charges as are carrier facilities. These include load coils and electronic line treatment equipment such as loop extenders and VF Repeaters. Because of this, the cost of these items is subtracted from the carrier cost prior to multiplying by the 1.25 factor.